

DISTRIBUTION OF DAMAGES IN CAR ACCIDENTS THROUGH THE USE OF NEURAL NETWORKS

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ABSTRACT

After a traffic accident the damage has to be fairly divided among the parties involved, and a ratio has to be determined. There are many precedents for this, and judges have developed catalogues suggesting ratios for common types of accidents.

The problem that "every case is different," however, remains. Many cases have familiar aspects, but also unfamiliar ones. Even if a case is composed of several familiar aspects with established ratios, the question remains as to how these are to be figured into one ratio. The first thought would be to invent a mathematical formula, but such formulae are rigid and speculative. The body of law has grown organically and must not be forced into a sleek system. The distant consequences of using a mathematical formula cannot be foreseen; they might well be grossly unjust.

I suggest using a neural network instead. Precedents may be fed into the network directly as learning patterns. This has the advantage that court rulings can be transferred directly and not via a formula. Future modifications in court rulings also can be adopted by the network. As far as the effect of the learning patterns on new cases is concerned, a relatively safe assumption is that they will fit in harmoniously with the precedents. This is due to the network's structure—a number of simple decisional units, which are interconnected, tune their activity to each other, thus achieving a state of equilibrium. When the conditions of such an equilibrium are translated back into the terms of the case, the solution can hardly be totally unjust.

INTRODUCTION

A.

I would like to begin my discussion on the distribution of damages in car accidents by referring to a legal case of inheritance from ancient Rome. This is not a far-fetched comparison; their children's

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inheritance was as important to the Romans as the state of our cars is to us Germans. Consequently, problems of distribution are similar.

In *The Digest of Justinian*,¹ the following case is reported: a husband, mortally ill and with a pregnant wife, writes his will:

si filius mihi natus fuerit, ex besse heres esto: ex reliqua parte uxor mea heres esto. si uero filia mihi nata fuerit, ex triente heres esto: ex reliqua parte uxor heres esto. . . .

[I]f a son is born to me let him be heir in respect of two thirds, let my wife be heir in respect of the remaining part; but if a daughter is born to me, let her be heir to the extent of a third; let my wife be heir in respect of the remaining part.²

Then the man dies. But the wife gives birth to twins: a boy and a girl.³

It was clear to the Romans that the solution to this case could not be drawn directly from the will. It is the testament's clear assumption that only one child would be born; the testator did not provide for the case of twins. A small-minded administration of the law would consider the will void: "suptili iuris regulae conueniebat ruptum fieri testamentum."⁴ The following interpretation would be more humane—"humanitate suggerente decursum est"⁵—and is in accordance with the testator's presumed wishes.⁶ It also met, according to Julian, the approval of Juventius Celsus (who apparently originally recorded the case):

dicendum est assem distribuendum esse in septem partes, ut ex his filius quattuor, uxor duas, filia unam partem habeat: ita enim secundum uoluntatem testantis filius altero tanto amplius habebit quam uxor, item uxor altero tanto amplius quam filia.

[T]he decision must be that the whole inheritance should be divided into seven parts, so that the son gets four of them, the wife two, and the daughter one; for in this way, in accordance with the wishes of the testator, the son will have as much more again as the wife and the wife as much more again as the daughter.⁷

At first glance this is an impressive solution, but less so when one looks again. With all due respect to the Roman jurists, I cannot approve of the decision. One-seventh of the inheritance is too little for

¹ DIG. 28.2.13 (Julian, Digest 29), reprinted in 2 THE DIGEST OF JUSTINIAN 821 (T. Mommsen, P. Krueger & A. Watson trans. 1985).

² *Id.*

³ *Id.*

⁴ *Id.*

⁵ *Id.*

⁶ *Id.*

⁷ *Id.*

the daughter. The difference between the daughter's portion and the son's portion is too great; the proportion of 1:4 is inadequate.

I am not even arguing from the point of view of our modern values, but this is also true with regard to the testator's presumed will. One can understand the testator's presumed will through a little mental experiment: if we assume that the husband had considered the case that his wife might die after giving birth, and that the property would have to be divided among a daughter and a son, would he not again have ordered a ratio of 1:2? From the testament one can surmise that a male should receive twice as much as a female.

Of course one can also take from the will the statement that the mother should receive twice as much as the daughter. But if one compares the different statements, there is an open contradiction in the case of three heirs—if the son can expect twice as much as the mother, and also twice as much as the daughter, then the mother must expect the same amount as the daughter and not twice as much.

Such a contradiction is by no means unusual. Whenever a just division is called for, and there are different statements as to how to divide, such conflicts can arise. This we know at least since Chaim Perelman's investigations of the "antinomies of justice."⁸ In fact, the problem of division remains if we alter the case and suppose the husband had known that his wife was bearing twins. He would have faced the same problem—how to unite his concepts that a male should receive twice as much as a female and a mother twice as much as a daughter. But the knowing testator retains the freedom of the legislator (e.g., the freedom not to tackle the problem). That this freedom is taken away from him in our case is a trick to pinpoint the problem.

What appears to be a peripheral legal problem is in fact an artifice to cast light on a general and fundamental problem. Celsus might have invented the case or come across it and recognized its importance. Either way, it is a stroke of genius.

B.

What is to be done in such contradictory cases? Most importantly, the individual postulates must be defined. This provides common ground for the argument. In some cases it will be possible to unify the contradicting postulates; to find a compromise.

Perhaps modern technology can be of assistance here: envision a machine which strives for equilibrium. Into this machine the case's controversial postulates are fed, creating a model of the conflict inside

⁸ C. PERELMAN, *DE LA JUSTICE* (Bruxelles 1945) (source on file with author).

the machine. When the strain inside this model has been resolved into a state of equilibrium, the solution is transferred back into the terms of the case.

It is not difficult to imagine a machine that strives for equilibrium. Yet, such a machine exists—it is called a set of scales. Scales have always been a symbol of justice.

Naturally, if one is not content with a symbol but wants a tool for justice, an especially subtle set of scales is needed. Modern science has already provided it—a neural network.⁹

In the case of the Roman testament I have consulted a neural network. I have entered into my computer, which runs a shell for such a network, the following four postulates:

1. If there is a mother and a son, and no daughter, the ratio for the property's division is to be 1:2.
2. If there is a mother and a daughter, and no son, the ratio for the property's division is to be 2:1.
3. If there is a daughter and a son, and no mother, the ratio for the property's division is to be 1:2.
4. If there is neither a son, nor a daughter, nor a mother, none of them receives anything.

They represent partly the testator's expressed will (1 and 2), partly his presumed will (3), and partly what can be concluded logically from these (4).

⁹ As for legal applications of neural networks see Philipps, Brass, & Emerich, *A Neural Network to Identify Legal Precedents*, 9TH SYMPOSIUM ON LEGAL DATA PROCESSING IN EUROPE (Bonn, Oct. 10-12, 1989) (source on file with author); Philipps, *Are Legal Decisions Based on the Application of Rules or Prototype Recognition? Legal Science on the Way to Neural Networks*, in 2 PRE-PROCEEDINGS OF THE III INTERNATIONAL CONFERENCE ON LOGICA, INFORMATICA, DIRITTO LEGAL EXPERT SYSTEMS 673, (A. Martino ed., Florence 1989) (source on file with author); Philipps, *Naheliegende Anwendungen Neuronaler Netze in der Rechtswissenschaft (Plausible Applications of Neural Networks in Legal Science)*, JUR PC, November-Dezember 1990, at 820 (source on file with author); Philipps, *Tû-Tû 2. Von Rechtsbegriffen und Neuronalen Netzen (Tû-Tû 2. On Legal Terms and Neural Networks)*, in RECHTSENTSTEHUNG UND RECHTSKULTUR (Kolloquium zu Ehren von Heinrich Scholler) (Philipps & Wittman eds., Heidelberg 1991) (source on file with author); Philipps, *Analogie und Computer (Analogy and Computer)*, ARCHIV FÜR RECHTS- UND SOZIALPHILOSOPHIE, Beiheft 44, at 275 (1991) (source on file with author).

Also, but more from the point of view of neuronal information retrieval, see Belew, *A Connectionist Approach to Conceptual Information Retrieval*, 1987 PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE AND LAW 116 (source on file with author); Rose & Belew, *Legal Information Retrieval: A Hybrid Approach*, 1989 PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE AND LAW 138 (source on file with author); Fernhout, *Using a Parallel Distributed Processing Model as Part of a Legal Expert System*, in 1 PRE-PROCEEDINGS OF THE III INTERNATIONAL CONFERENCE ON LOGICA, INFORMATICA, DIRITTO LEGAL EXPERT SYSTEMS 255 (A. Martino ed., Florence 1989) (source on file with author).

Then the network was asked about the critical situation with three heirs.¹⁰ This was its solution: if there is a daughter, a mother, and a son, the ratio must be 2:3:4. Thus the daughter receives two-ninths of the property, the mother three-ninths, and the son four-ninths.

This appears to be a decent compromise. Between daughter and son the ratio of 1:2 is retained, and the mother's portion lies in between, as was also the testator's will. The only other plausible solution that I could think of is 1:2:3, where the ratio of 1:2 is retained between daughter and mother. Nevertheless, one-sixth of the inheritance is still a bad deal for the daughter.

I.

What does this case of inheritance have to do with the division of damages in traffic accidents? A great deal, if one looks closely. First, the principle of the ratio is prevalent: nobody receives everything, but rather something is split among a few people according to a specific ratio. In accidents, however, it is not property, but the liability of paying for the damage that is divided. Second, there are certain postulates for the ratios, accepted by the courts. It is possible, however, that several different ratios may apply, and it is unclear how they are to be combined. Third, it is likely that a third party (or even a fourth and a fifth) has a part in the car accident and, as a result, the ratio between the first and the second differs from the ratio between the first and the third. The question now is how this should be figured into one ratio.

Today, it is increasingly expected of the courts to divide assets and liabilities proportionally instead of an all-or-nothing award. The reasons may be many. One of them can be derived from the conditions of traffic. These conditions are such that damage to another often follows from someone's inattentiveness. The same conditions make the victim's carelessness increase the risk for damage. In some cases the damaging and the damaged cannot be distinguished. Consequently, everyone involved in the accident damages the other and suffers damage himself.

One participant's fault has to be combined with the other's con-

¹⁰ For the calculations, a fully interconnected back-propagation network with three input units, three output units, and two hidden units were used. The relation of 1:2 was expressed by output values of .33 and .66. The network very quickly learns the simple prototypes; possibly in only 80 cycles. The unfamiliar input of 1,1,1 (mother, son, and daughter exist) results in outputs of approximately .30, .45, and .60 (divided by 1.5 the result is .20, .30, and .40). Typically, the output of neural networks consists of approximations.

tributory fault. This calculation is not easy as fault does not have to be proportionate to the damage. The smallest mistake—amplified by technology—may cause enormous damage. Thus the relation between cause and effect is typically not linear. The law takes this into account by establishing strict liability—liability regardless of fault. How fault and strict liability are to be combined, however, remains unclear.

Before everyone's eyes the distinction of the damaging and the damaged is lost, and everyone sees how easily he can be in one or the other position. Understandably, popular conviction can no longer distinguish between black and white, between all or nothing, with the nineteenth century's assurance. Differentiating judgment is called for. There may be other reasons along the same lines for this zeitgeist; the reasons given are already plausible enough. The growing demand for differentiated ratios in court rulings has some powerful social reasons behind it. But so far little has been done in compliance with this demand, outside of improvisation and guess-work. There are not even hints of a technique in jurisprudence for this problem that would be comparable to the technique of subsumption and interpretation which has been established over the course of centuries.

In all "fair" and "adequate" decisions, we are doing something we do not really know how to do. We are doing it because it has to be done. Because of the increasing number of instances where such a decision is necessary, the inadequacy of our approach is increasingly felt. Nevertheless, the growing awareness of the problem has not resulted in an adequate solution.

II.

Neural networks consist of several "neurons"—simple decisional units which are interconnected. The neurons affect one another. For example, activated units can communicate with their neighboring units and activate them in turn. Neurons may also restrain their neighbors, suppressing their activity.

The neurons are activated by "impulses" from the outside world, which are received by the input units. The network reacts using output units. Whether the reaction is correct may be determined by a comparison with learning patterns (at least this is the prevalent system of back-propagation). Any deviation from the expected value is fed back into the network until the interconnected units' activity has reached a state of equilibrium. The network now has learned the correct relation of input and output, of impulse and reaction.

Remarkably, the network also tolerates contradicting learning

patterns. The equilibrium attained by the units will be a compromise between the patterns.

The same applies to patterns missing certain information; the network not only reacts to input with which it is already familiar, but it also finds a reaction to the new input patterns. While maintaining the equilibrium between the interdependent units, it attempts to harmoniously adapt to the "precedent."

In complex cases, learning cannot be handled by input and output units alone; inner, "hidden" layers of units have to be incorporated. A model or an "internal representation" of the world is created. This internal representation will vary greatly according to the structure of the network. This variation will become apparent when the network has to react to unfamiliar input. Depending on the nature of the internal representation, the network's reactions differ. It will always react in a way similar to the "closest" familiar input pattern according to how "similar" and "close" are defined by the network's internal model.

Neural networks are governed by principles which originate from biology. But the law also strives for a state of equilibrium. Conflicting interests have to be settled, antagonistic principles have to be observed equally. Gaps in the legal system have to be filled in a way consistent with existing precedent. Justice has always—from ancient times up to the present—been described in terms and models of equilibrium and compromise.

The attempt to utilize neural networks for legal cases, however, is not about philosophical speculation, but about something very down-to-earth—an instrument, capable of suggesting solutions for certain types of cases. The neural network is regarded as a machine which establishes internal equilibrium. Legal problems are transposed onto this machine, and the machine's reaction is translated back to the case.

These terms—neurons and equilibrium—have a provoking metaphorical ring to them. Nevertheless, I will show their meaning in concrete suggestions for decisions. Concrete decisions can be made a subject of argument; their quality can be tested.

III.

After a traffic accident the damage has to be divided fairly among the parties involved, and a ratio has to be determined. There are many precedents in German law, and judges have also developed cat-

alogues suggesting ratios for common types of accidents.¹¹ These catalogues can be very handy. On the other hand, they are criticized for being too rigid. My idea is to make use of a distribution catalogue that is more flexible by employing a neural network. The network would detect hidden inconsistencies in the catalogue, and it would also fill the gaps in the catalogue by interpolation. "Interpolation" is also one of Professor Zadeh's "key" words.¹²

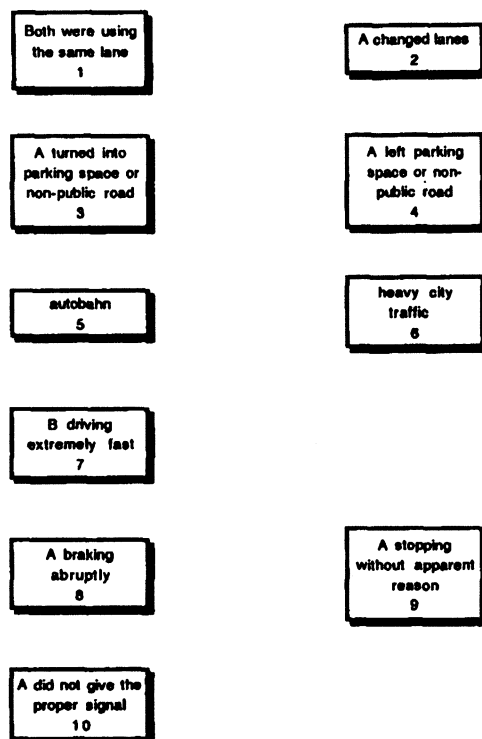
A network for damage distribution would not try to cover all conceivable accidents. Rather, several networks would be used, one for each particular type of accident. With several types of accidents within one network, too many input units would be needed, and the units would not be properly interconnected. (Each unit should be given an interpretation in such a way that interconnections between units are meaningful—to the greatest possible extent.)

The network I am going to demonstrate simulates the collision of two motorized vehicles driving in the same direction. The network has ten input units interpreted as follows:

¹¹ Cf. Bursch & Jordan, *Typische Verkehrsunfälle und Schadensverteilung*, VERKEHRSGERICHTSTAG IN GOSLAR (VGT) 231 (1985) (the "Hamburger Qotentabelle" (Hamburg Table of Ratios)) (source on file with author); and its Munich counterpart, Krumbholz, Paul & Brüseken, *Haftungsquoten bei Typischen Verkehrsunfällen*, NEUE ZEITSCHRIFT FÜR VERKEHRSSRECHT (NZV) 168 (1988) (Munich Ratio Catalogue) (source on file with author); cf. also the compilation of court rulings published by the ADAC (German Automobile Club): O.E. Hitzel, *Schadensverteilung bei Verkehrsunfällen* (1980) (source on file with author).

¹² L. Zadeh, *Fuzzy Logic: Principles, Applications, and Perspectives*, Speech at symposium entitled "Decision and Inference in Litigation" at Benjamin N. Cardozo School of Law (Mar. 24-26, 1991).

FIGURE 1



B bumped into A input units

Ten input/output connections were entered as learning patterns, one pattern for each input unit. Each input combination stands for a legal case; the output values represent distribution ratios. According to German practice, the possible values are restricted to a nine level scale¹³ (some courts, however, prefer a different scale that uses simple fractions: 1:1; 1:2; . . . ; 1:5):

¹³ The conversion formula for the ratios is: $(b/a-1)$ if $a \geq b$, and $(1-a/b)$ if $b > a$.

-1.00	100:00	very large against the first party
-.75	80:20	large against the first party
-.57	70:30	medium against the first party
-.33	60:40	small against the first party
0.00	50:50	negligible; balance status
.33	40:60	small against the second party
.57	30:70	medium against the second party
.75	20:80	large against the second party
1.00	00:100	very large against the second party

As for the number of learning patterns, computer scientists may be getting an eerie feeling. Theory has it that there should be numerous learning patterns. With ten input units, there are as many as 1024 possible input combinations (2 to the power of 10), and each of them can be connected to different outputs. Can thousands of conceivable connections reasonably be guided by as few as ten learning patterns?

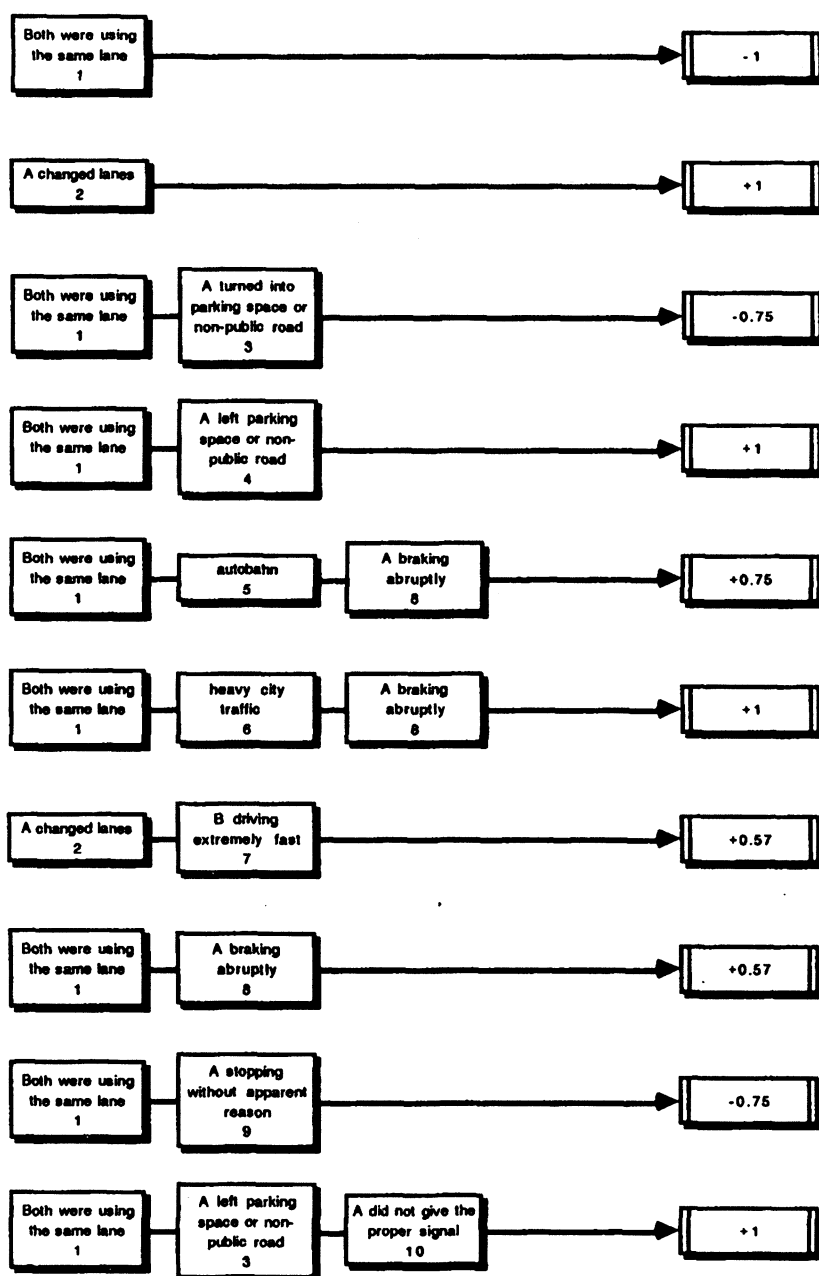
In answering this question, two things should be considered. First, only a few of the input combinations which are logically possible can be interpreted as constellations which make sense from a legal point of view. Therefore, the user will look only for those few. Second, it is most important to choose learning patterns which are not only correct, but prototypical.¹⁴ For example, you can determine any cube by four points. But if the points are poorly selected, one hundred points may not be enough.

The ten learning patterns include:¹⁵

¹⁴ Philipps, *Are Legal Decisions based on the Application of Rules or Prototype Recognition?*, *supra* note 9.

¹⁵ Adapted from the *Munich Ratio Catalogue*, *supra* note 11 (altered slightly to adopt them to the values of the nine level scale).

FIGURE 2



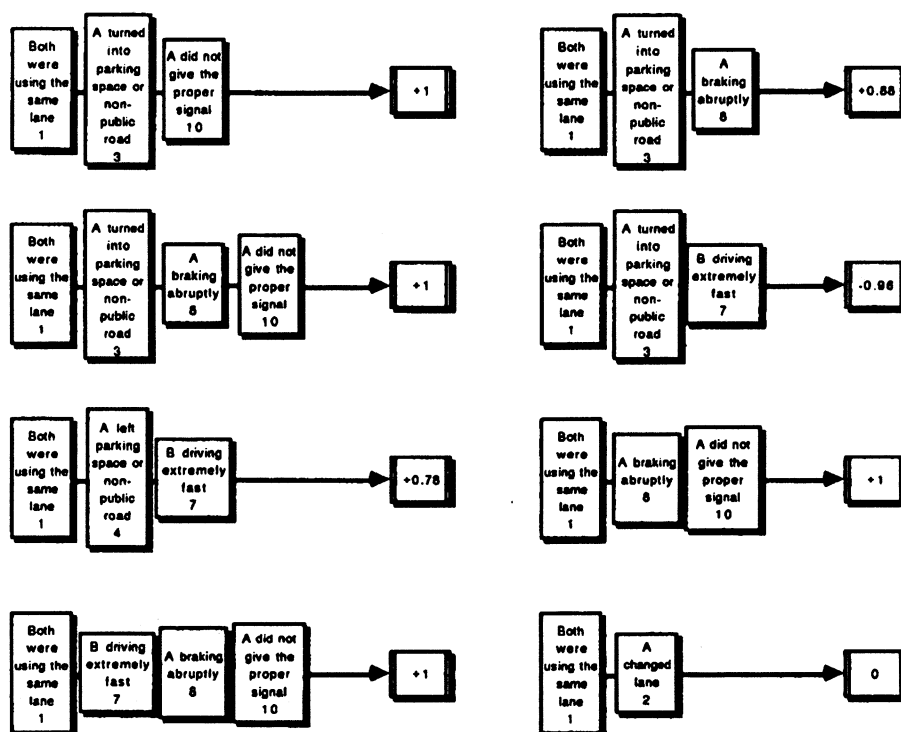
learning patterns

+1: A pays everything
-1: B pays everything

Incidentally, if the patterns are viewed as a set of statements, they are contradictory. The first one states categorically, without any logical loophole for a possible exception, that if "[b]oth were using the same lane" the ratio shall be -1. However, if the second condition is added (that "A left parking space . . .") the ratio shall be +1. This is the way the law operates. The more specialized rule is "stronger" and forces out the more generalized one. The reason is that the more special association is stronger than the more general one; it is not a question of logic but of "psychology."

Learning the patterns takes a 386-computer a few minutes. Afterwards new constellations can be entered, and the conclusions the network finds can be observed. Here is a sample of interpolated input/output combinations:

FIGURE 3



conclusions drawn by analogy

At first glance, each of them looks reasonable. But for a test, one should change the rate by which the network learns and make it learn the patterns again. (A different learning rate means the system can

approach its target by small steps or by big steps. In the latter case, it will reach the target vicinity earlier but perhaps miss the target several times. It is like playing golf.) If the network draws different conclusions from the same input at different learning rates, this may be a sign that the learning patterns are inconsistent. As for our example, most solutions seem to be stable. But not the connection 1, 7, 4 = > .78. (Both were using the same lane; *A*, however, left a parking space; but *B* was driving extremely fast.) At different learning rates, you get .87, .97, or .61 as an output.

I have tried using different structures for the network, but its performance did not improve. Now I assume that the input units 4 and 7 are too isolated in the network compared to the strain that is imposed by this connection; 4 has to totally reverse the normal result of 1 and is partially reversed by 7. These units will have to be backed by further learning patterns.

I mentioned earlier that there are input combinations that make no sense from a legal point of view. However, it can be advantageous to enter semantically contradictory combinations in cases where a decision between input options is difficult. If, for example, a vehicle has changed lanes before the collision took place at a distance from the following car which could perhaps be regarded as safe, it is difficult to decide whether it is a one lane or a two lane accident (our last examples of "conclusions drawn by analogy"). In such cases, the German courts use an average, in this case a ratio of 0 (50:50). So does our network.

IV.

One of the neural network's most important assets is the possibility of entering precedent rulings as learning patterns. The trends in court rulings are integrated directly into the network, even if they modify earlier precedents. In theory, of course, a mathematical formula which could do the same always exists. And yet, how is the formula to be discovered, and how is it to be kept up to date with the trends in the courts? It would certainly be more than mathematicians could do, not to mention jurists. But even if a formula solving all the common cases could be found, what guarantee can there be that the distant consequences, which cannot be foreseen, will not be unjust? A neural network does indeed guarantee it. The neurons strive for equilibrium, and when the conditions of the equilibrium are translated into the terms of the case, the resulting solution cannot be totally unjust.

The neurons in a network act like a group of people in a very

crowded room—they are resting side by side, and they have accommodated to their neighbors. From time to time, however, one of them changes his position. Then his neighbors have to move, and the neighbors' neighbors as well, until, after a few shoves, everyone has found a new comfortable position. His immediate neighbors will be affected first, but through the movement of the neighbors, and of their neighbors in turn, the need to stir might extend even to a remote corner. Some, of course, will not budge; they are comparable to the fixed learning patterns.

This is not to say that the people in the room have indeed attained the ideal degree of comfort. A better solution may well have been possible. But who is to calculate the perfect position given everyone's different sizes and positions? And, most importantly, before you have finished calculating, someone will have moved again.